Ergonomics
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713701117

University students' notebook computer use: lessons learned using e-diaries to report musculoskeletal discomfort

K. Jacobs[a]; G. Foley[b]; L. Punnett[b]; V. Hall[c]; R. Gore[b]; E. Brownson[c]; E. Ansong[c]; J. Markowitz[c]; M. McKinnon[c]; S. Steinberg[c]; A. Ing[c]
[a] Boston University Sargent College, Department of Occupational Therapy, Boston, MA, USA [b] University of Massachusetts Lowell, Lowell, MA, USA [c] Boston University, Boston, MA, USA

Online publication date: 02 February 2011

To cite this Article Jacobs, K. , Foley, G. , Punnett, L. , Hall, V. , Gore, R. , Brownson, E. , Ansong, E. , Markowitz, J. , McKinnon, M. , Steinberg, S. and Ing, A.(2011) 'University students' notebook computer use: lessons learned using e-diaries to report musculoskeletal discomfort', Ergonomics, 54: 2, 206 — 219

To link to this Article: DOI: 10.1080/00140139.2010.544764

URL: http://dx.doi.org/10.1080/00140139.2010.544764

Ergonomics
Vol. 54, No. 2, February 2011, 206–219

University students' notebook computer use: lessons learned using e-diaries to report musculoskeletal discomfort

K. Jacobs[a]*, G. Foley[b], L. Punnett[b], V. Hall[c], R. Gore[b], E. Brownson[c], E. Ansong[c], J. Markowitz[c], M. McKinnon[c], S. Steinberg[c] and A. Ing[c]

[a]*Boston University Sargent College, Department of Occupational Therapy, Boston, MA, USA;* [b]*University of Massachusetts Lowell, Lowell, MA, USA;* [c]*Boston University, Boston, MA, USA*

(*Received 26 May 2010; final version received 21 November 2010*)

The objective of this pilot study was to identify if notebook accessories (ergonomic chair, desktop monitor and notebook riser) combined with a wireless keyboard, mouse and participatory ergonomics training would have the greatest impact on reducing self-reported upper extremity musculoskeletal discomfort in university students. In addition to pre-post computing and health surveys, the Ecological Momentary Assessment was used to capture change in discomfort over time using a personal digital assistant (PDA) as the e-diary. The PDA was programmed with a survey containing 45 questions. Four groups of university students were randomised to either intervention (three external computer accessories) or to control. Participants reported less discomfort with the ergonomic chair and notebook riser based on the pre-post survey data and the e-diary/PDA ANOVA analysis. However, the PDA data, adjusted for the effect of hours per day of computer use, showed no benefit of the chair and limited benefit from the riser.

Statement of Relevance: University students' use of notebook computers has increased. This study found evidence of a positive effect of an adjustable chair or notebook riser when combined with ergonomic training on reducing discomfort. Daily notebook computer use of 4 h was confirmed as a risk factor. Without some form of ergonomic intervention, these students are likely to enter the workforce with poor computing habits, which places them on the road to future injuries as technology continues to play a dominant role in their *lives*.

Keywords: human–computer interaction; musculoskeletal; office ergonomics; participative ergonomics

1. Introduction

Today's university students are part of the millennial generation, born between 1982 and 2000 (Lancaster and Stillman 2010). They are the children of the baby boomers and are sometimes called generation Y or the Net generation and are the first truly digital generation. Altogether, 75% have created a profile on Facebook or some other social networking site (Samuelson 2010). The use of notebook computers has become integral to these talented and tech-savvy students as they become immersed in technology in both their academic and social networking daily lives. The term 'notebook' originated when heavier laptops weighing closer to 10 lbs were redesigned to be lighter. Today, the terms 'notebook' and 'laptop' are used interchangeably. Students arrive on campus with an array of mobile devices, such as smart phones, iPods and tablets in addition to their notebook computer. From 2006 to 2009, ownership of a notebook computer by university students increased from 66% to 88% and the trend is expected to continue as students embrace their portability, lightweight and space-saving features (Smith *et al*. 2009). More than nine out of 10 freshmen (93.9%) owned a notebook computer. Desktop ownership has decreased from 71% to 44% during this same timeframe (Smith *et al*. 2009). The rapid growth of portable PCs such as the notebook computer is the major reason for current and future PC expansion. In 2009, US PC shipments totalled 70 million with notebooks accounting for 42.5 million (60.7%) of these shipments. IDC, a market research firm, has estimated that US PC sales will reach 117 million units by 2014 with notebooks constituting about 79% or about 92.4 million notebook PCs to be sold.

Students' use of notebook computers in class has increased as universities integrate technology into the classroom. With this increased use of notebooks comes the increased risk for students to develop upper extremity musculoskeletal disorders (UEMSDs). Computer-related discomfort in childhood and adolescence may be of particular concern as the musculoskeletal system and posture are still developing (Straker *et al*. 2009a). Katz *et al*. (2000) brought to

*Corresponding author. Email: kjacobs@bu.edu

ISSN 0014-0139 print/ISSN 1366-5847 online

DOI: 10.1080/00140139.2010.544764
http://www.informaworld.com

light the prevalence of musculoskeletal discomfort in university students. Their cross-sectional study revealed that 41% of university students experienced computing-related musculoskeletal symptoms while using a computer.

University undergraduate enrolment was approximately 18.0 million in the autumn of 2008. Over 50% of surveyed university students experience pain that they attribute to computer use (Menéndez *et al.* 2008) and one in seven said they had pain after working for $\leq$ 1 h on the computer (Hupert et al. 2004, Jacobs *et al.* 2009). Thus, there exists the potential for 2.52 million students to develop UEMSDs before they even enter the workforce. The Bureau of Labor Statistics in 2009 reported that musculoskeletal disorders (MSDs) accounted for 29% of all workplace injuries and illnesses requiring time away from work in 2008. Since duration (in years) of exposure leads to cumulatively increasing MSD risk (Punnett and Bergqvist 1997), this has potentially serious implications for their future health.

To promote the health of this next generation of employees, universities need to be aware of how students may be at risk for developing computer-related musculoskeletal injuries, such as carpal tunnel syndrome, neck pain or low back injuries since they spend much of their day in static sitting positions, either in classes or while working on their notebook computers.

1.1. Musculoskeletal risk factors related to notebook computer use for university students

Students' use of their notebooks for academics, social networking and as a source of entertainment (Facebook, MySpace, iTunes and YouTube) typically translates into increased daily usage. Based on the ECAR 2009 study of undergraduate students (Smith *et al.* 2009), which analysed the responses of 30,616 freshman, seniors and community university students at 114 US institutions, students spend an average of 21.3 h per week actively doing Internet activities for school, work and recreation and 8.8% spent more than 40 h per week. This varies by discipline; engineering majors averaged 25 h per week and education majors the least at 19 h per week. Nine out of 10 (90.3%) use social networking sites with more than three-quarters (76%) reporting daily use. Prior findings of computer use of more than 3 h per day may double the risk of developing an UEMSD, prolonged use of a mouse-pointing device also increases risk (Chang *et al.* 2007).

Risk factors for UEMSDs related to notebook computer use by university students are likely very similar to those cited for computer use in general (Punnett and Bergqvist 1997):

- Frequency of use – days per week, number of times per day.
- Duration of use – cumulative hours of computer use per day.
- Intensity – hours of computer use per day without taking a rest break.
- Repetition – keyboarding: rapid, repeated and sustained exertions.
- Frequent or prolonged static muscle contractions – clicking and scrolling.
- Awkward postures – use of the notebook on the lap or in non-neutral body postures.
- Static postures – neck strain: flexion exceeding 20° viewing monitor screen.
- Contact stress – direct pressure of wrists/ forearms/hands on sharp/hard desk edges.
- Lighting – poor lightening or glare resulting in visual discomfort, such as eye strain.

Recent studies (Bernard et al. 1997, Jenkins *et al.* 2007, Hupert *et al.* 2004) found a growing body of epidemiological evidence that supports a causal relationship between repetition, force, posture and UEMSDs. This takes into account not only the amount of time that students spend at their computer, but also the posture that they maintain while sitting at their computer and the type of activity performed, whether it be typing, scrolling or clicking of the mouse. Students in these studies resided in dorms and 54% (n = 116) reported upper extremity (UE) pain with computing in the past 2 weeks, 41% said they were functionally limited by UE pain. The greatest prevalence of pain was in the neck, shoulders and wrist. Hupert *et al.* (2004) found 42% of undergraduates at a private northeastern university reported UE pain with computing in the past 2 weeks and 41% said they were functionally limited by UE pain. With this growing evidence showing the epidemic plaguing university students, one study did find a promising solution to this alarming issue. Robertson *et al.* (2002) conducted a pilot intervention study examining the effects of a participatory ergonomic training programme, which taught university students computer ergonomics principles and how to reorganise and adjust their workstations. It was successful in increasing participants' ergonomic knowledge from 69% of test items answered correctly pre-training to 82% post-training and they achieved 100% accuracy in identifying ergonomic problems and proposing solutions in workstation assessments.

While the majority of the recent literature focuses on computer use and how that affects musculoskeletal pain and discomfort, notebook computer use has not been addressed until recently (Sommerich *et al.* 2002). Menéndez *et al.* (2007) began to look at variables related to computer use emphasising computing related postures, use patterns and UEMSDs in university students during the spring 2004 semester. Variables included computing locations, activities and duration of use. They found that 55% of the participants were using a notebook computer, although did not note if any notebook accessories were being used. Menéndez et al. (2008), in a continuation of this study, did find that notebook computer users reported a higher rate of musculoskeletal symptoms when compared with desktop users.

1.2. Ergonomic exposure assessment in undergraduate university students

Given the notebook computer's multi-faceted use and the physical constraints of the school/dorm room environment within which it is used, the physical characteristics of its use are frequently mismatched to the body's needs. Students typically spend a large portion of their day in a static sitting position, in a classroom, the library or at a desk in their dorm room on a hard wooden or plastic chair that has limited support. Dorm room desks are often small, cluttered and like the chairs are not adjustable, which may contribute to awkward postures. Computing is done in the dorm room at the student's desk, on the bed or on the floor, which would be even more difficult to rectify except through education.

When the notebook used without any peripherals is set on a desk or table, the keyboard is then usually too high, which causes hunching of the shoulders and contact between the hand/wrist/forearm and the hard desk edge. In addition, the monitor is too low, which pulls the head and neck forward and down, increasing the likelihood that neck flexion exceeds 20°, which may cause neck strain and discomfort (Straker *et al.* 1997). More non-neutral postures and muscle load in the neck and upper extremities were observed and more discomfort was reported when using a notebook than when using a desktop computer (Straker *et al.* 1997, Villanueva *et al.* 1998). Asundi et al. (2010) found postures assumed when using a notebook on a lapdesk were less neutral than those associated with using a desktop computer configured with an external monitor, keyboard and pointing device.

To create a proper ergonomic set-up for the notebook, a variety of notebook accessories, such as an external keyboard, ergonomic computer workstation chair, external monitor, external mouse and a notebook riser, are available. Use of such notebook accessories combined with ergonomic training may be a solution to the occurrence of UEMSDs in notebook computer users (Sommerich *et al.* 2002). Jacobs *et al.* (2009) found that students who used external notebook accessories (riser, wireless keyboard and mouse), and participated in an ergonomics workshop with follow-up, self-reported less notebook computer-related discomfort post-study (49%) as compared with pre-study (64%), when no external devices had been used.

1.3. Objectives

The objective of this pilot study was to expand upon the previous study's findings (Jacobs *et al.* 2009) to identify which notebook accessory (ergonomic chair, desktop monitor and notebook riser) combined with participatory ergonomics training would have the greatest impact on reducing self-reported UE musculoskeletal discomfort in university students.

The change in discomfort over time was examined and daily computer usage patterns were identified for training, policy and future research. In addition, the aim was to identify and adjust for potential confounding variables; change in computer usage (hours per day) over time and change in discomfort over time as a function of usage. The following hypotheses are proposed:

> Hypothesis 1: Participants in the chair group will experience the best outcome in terms of a decrease in self-reported UE musculoskeletal discomfort.
>
> Hypothesis 2: The combination of external notebook computer accessories and participatory ergonomic training are effective strategies in reducing university student's self-reported UE musculoskeletal discomfort and students will find the ergonomic chair to be the most convenient accessory.

2. Methods

This study added a method of data collection, Ecological Momentary Assessment (EMA) using a personal digital assistant (PDA), for greater precision to capture change in discomfort over time. Its use in the self-reporting of discomfort within a university student population has been limited to research conducted by Menéndez *et al.* (2007, 2008).

2.1. Study participants

A convenience sample of undergraduate students was recruited from a single student residence (dormitory) at a private university in the New England area of the United States. Flyers advertising the study were circulated throughout the dormitory; participants were also recruited by the author through direct personal contact. Only students aged $\geq$ 18 years who reported using a notebook computer as their primary computer were invited to participate. Two separate recruitments took place for this multi-term study: one in autumn 2007 (autumn group); the second in spring 2008 (spring group). The maximum number of students per trial was constrained by the number (48) of Palm Z22 PDAs (Palm Inc. 950 W Maude Ave., Sunnyvale, CA, USA) available, since each student required one in order to complete the daily EMA surveys. Institutional Review Board approval was obtained from Boston University and informed consent was obtained from each participant.

2.2. *Study design*

This pilot study mixed design was a randomised control trial using repeated measures to evaluate the effects of computer accessories combined with training on reducing musculoskeletal discomfort. Participants were assigned to one of four groups (Table 1) using a random number table. Two pilot studies were conducted, one in the autumn with a data collection period of 9 weeks and one in the spring lasting 7 weeks. The data were not pooled due to different lengths of weeks and beginning at different times within a semester. At baseline (1–7 d before the intervention began) and again at the completion of the intervention, all participants completed an ergonomics quiz and The Boston University Notebook Computer and Health Survey. This survey was adapted from the one developed by Katz *et al*. (2000). The adaptation focused the survey on notebook computing rather than desktop computing. The survey has face validity. Prior to the intervention, anthropometric measurements were taken to compare that participants were of similar body size. The students were photographed in their dormitory room while using their notebook computers in postures that they assumed naturally.

The control group received participatory ergonomics training (T), an external keyboard (K) and wireless mouse (M), the chair group received an adjustable ergonomic workstation chair and T + K + M, the monitor group received an external desktop monitor and T + K + M and the riser group received an external notebook riser and T + K + M.

Upon completion of training in computer ergonomics, each participant in group nos. 1–4 was loaned a PDA, which contained a 45-question survey. PDA technology has been used in clinical research for nearly 20 years and is considered a superior data collection method as compared with paper diaries (Koop and Mösges 2002). The use of the PDA for the repeated measure survey was part of the EMA method for obtaining repeated real-time assessments of subjects' behaviour and experience in their natural environment. Its benefit is to minimise recall bias, maximise validity and capture change over time. Over the duration of the study (up to 3 months), participants met weekly with the researchers for feedback related to ergonomics and uploading of PDA data from the previous week.

2.3. *Survey methods and instruments*

2.3.1. *Self-report methods*

There were three self-report methods used: the Pre/Post Boston University Notebook Computer & Health Survey; the EMA/PDA 45 questionnaire survey; the Pre/Post Ergonomics Quiz (Table 2). The survey and quiz were completed at baseline and again post-intervention. The PDA questionnaire collected musculoskeletal discomfort symptoms on a daily basis throughout the study.

The Ergonomics Quiz was composed of 10 true/false content items from the participatory ergonomics training and was administered to participants prior to completion of The Boston University Notebook Computer Survey at baseline and post-intervention. The objective of the quiz was to ascertain the

Table 1. Study design.

Group	Control	Chair	Monitor	Riser
Autumn 2007 – Days = 62, n = 48	n = 12	n = 12	n = 12	n = 12
Spring 2008 – Days = 45, n = 40	n = 10	N = 10	n = 9	n = 11
Ergonomics Quiz: Pre & Post	X	X	X	X
BU Notebook Health & Computer survey: pre – post	X	X	X	X
Participatory Ergonomics Training	X	X	X	X
Accessory: keyboard and mouse*	X	X	X	X
Accessory: Intervention	None	Chair	Monitor	Riser

BU = Boston University.

*All subjects were provided with the same wireless mouse and keyboard.

Note: Autumn semester began 4 September 2007, ended 12 December 2007, week 1 began 4 weeks into the semester. Holidays shortened weeks 6 and 8 by 1 d, week 7 by 2 d. Spring semester began 16 January 2008, ended 1 May2008, week 1 began after spring break, 9 weeks into the spring semester. Holidays shortened week 6 by 1 day.

Table 2. Exposure with corresponding survey instruments and methods.

Exposure	Self-report	Observational
Computing patterns and usage	Pre/Post BU Notebook Computer & Health Survey PDA 45-question survey	
Computing posture	Pre/Post Ergonomics Quiz	Photos (dorm-room)
Upper extremity musculoskeletal discomfort	Pre/Post BU Notebook Computer & Health Survey PDA Survey 45 questions	

BU = Boston University; PDA = personal digital assistant.

participant's knowledge and beliefs about ergonomics. The sum of all the correct answers was calculated as the ergonomic score.

The Boston University Notebook Computer Survey was used to record demographic information and document physical and behavioural change, such as rest breaks and discomfort associated with computer usage. This survey has been used in studies of university students and was adapted to focus questions around the notebook rather than desktop computer (Katz *et al*. 2000, Amick *et al*. 2003, Hupert *et al*. 2004, Jenkins *et al*. 2007, Menéndez *et al*. 2007, Jacobs *et al*. 2009).

The EMA protocol would require the participants to complete multiple surveys throughout the day over the duration of the intervention. The participant's Palm Z22^{TM} PDA was programmed to beep randomly seven times per day every 3.0–3.5 h with a survey, adapted from one used by Menéndez *et al*. (2007). This survey used a program from an open source, the National Science Foundation-funded experience-sampling program, found on http://www.experience-sampling.org, which successfully tested its usability. The e-diary protocol of data collection could result in 20,832 programmed 'beeps' for the autumn study (62 d $\times$ 7 beeps/d per participant $\times$ 48 participants) and 12,600 'beeps' for the spring study (45 d $\times$ 7 beeps/d per participant $\times$ 40 participants). The 45 questions covered current musculoskeletal discomfort, location of student when using computer (classroom, dormitory, library, etc.), computer set-up (desk, table, bed, floor, etc.) and use of external notebook computer accessories (mouse, keyboard, trackball, etc.). Typical completion time was about 2 min and all participants received instructions on how to use their PDAs and were instructed to carry the PDAs on their person during their usual daily activities for the duration of the study. To minimise the potential for disruption (PDA beeping) during class, a memo was provided to each participant with the recommendation that a copy be provided in advance to their instructors.

Answering PDA question number 1, 'Are you using a computer now?', established compliance. To encourage and reward compliance, during weekly study visits to retrieve PDAs for uploading the prior week's data, participants were given snacks, feedback (ergonomic topics related to healthy computing or prompts to improve their response rate) and a \$10 iTunes gift card. The incentive programme was enhanced for the spring group by including the opportunity to win an iPod.

2.3.2. *Participatory ergonomic training*

Multiple participatory ergonomic training workshops were delivered by the primary researcher, who is an occupational therapist and a Board Certified Professional Ergonomist and each group was limited to five or fewer. The content and format was the same as the first study (Jacobs *et al*. 2009).

2.4. *Data and statistical analysis*

All data were entered into Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA, USA) and analysed using SAS version 9.2 (SAS Institute, Cary NC, USA). To test mean differences in discomfort between the control group and the three accessory groups, one-way ANOVA/Scheffe was used with significance set at the 0.05 level. Categorical data were summarised using percentages and analysed using the chi-square test for independent samples. Continuous variables were summarised using means and standard deviations. Pearson product-moment correlation and Spearman rank correlation were used to test the strength of association between continuous variables, discomfort and hours per day of computing.

Of the 45 questions to be completed each time the participant was beeped, 19 focused on current physical discomfort: one item each for left and right side of hands, fingers, elbows, forearms, upper arms, shoulders, two items each for left and right wrists, plus the neck, lower and upper back. Discomfort was measured on a 5-point Likert scale for symptom intensity, ranging from 'none' (1) to 'very severe' (5). The 19 discomfort questions were averaged into a single 'UE Index' for each participant, where the index equalled 1 for no discomfort in any site

(Sauter *et al.* 1991, Katz et al. 1994, Baker *et al.* 1999, Strazdins and Bammer 2004, Gold *et al.* 2006).

To characterise the change in discomfort (UE Index) over time by group, linear regression models to estimate the slope were constructed for each subject with UE Index as the dependent variable and two time-related independent variables, 'Pda_date' (the date the survey was completed) and 'usage' (mean hours/d of notebook computer use). A lower threshold of statistical significance was decided upon a priori as the pilot studies were basic, exploratory research (Menéndez et al. 2008). Models with a negative slope for 'Pda_date' ($p \leq 0.10$) represented a decrease in discomfort, while a positive slope indicated increasing discomfort. Thus, each subject could be characterised as having an increase, a decrease or no change in discomfort over the duration of the study.

3. Results

3.1. *Study population*

The two studies conducted during the 2007–2008 academic year utilised a separate group of undergraduate university students during each term: an autumn group (2007 autumn term: 62 d); a spring group (2008 spring term: 45 d). Autumn consisted of 48 university students, 23 (48%) females and 25 (52%) males and spring consisted of 40 participants, 19 (49%) females and 21 (51%) males. Table 3 lists participants' characteristics at the start of the study (baseline). Altogether, 77% of the participants in the autumn group were freshman, as were 92% in the spring group. The majority of the participants in both studies were science/engineering majors, 82% for autumn and 71% for spring. Altogether, 59% described themselves as Caucasian in autumn, as did 69% in spring.

3.2. *Participation rate: Boston University Notebook and Computing Health Pre/Post Survey and PDA Questionnaire*

Baseline Computing and Health Surveys for Pre/Post intervention were completed by 48 of autumn and 39 of spring participants (100% and 98% participation, respectively). All of the participants received PDAs. By weeks five and six, the number of subjects responding to the PDA questionnaire on a weekly basis declined by 30%. During the final 2 weeks, participation had declined to 47% (autumn) and 44% (spring).

3.3. *PDA Questionnaire: students' compliance to repeated EMA*

Each PDA was programmed to beep seven times per day and the participant was to tap the PDA screen to confirm the beep and begin the survey. Altogether, 48 autumn participants completed 2,009 surveys, a 16% compliance rate (surveys completed based on 12,042 confirmed PDA beeps) Altogether, 40 spring participants completed 1,909 surveys, a 24% compliance rate (surveys completed based on 7,867 confirmed PDA beeps). This is described in Figure 1 and answering PDA question number 1, 'Are you using a computer now?', established compliance. In autumn, the control group had the lowest compliance rate of 6%, with the remaining groups in the 10–11% range. In spring, the control group had the highest compliance rate of 18%, with the remaining three groups in the 13–15% range. If compliance was based on the 'programmed beeps', the overall rate would have been lower, 10% for autumn and 15% for spring. The total number of survey responses from each participant in autumn ranged from 1 to118 (mean = 42) out of a potential maximum of 434

Table 3. Participant characteristics: pre-survey (baseline) results.

	Fall: Pre-survey (baseline)					Spring: Pre-survey (baseline)				
Characteristic	Overall	Control	Chair	Monitor	Riser	Overall	Control	Chair	Monitor	Riser
Participants (n)	48	12	12	12	12	40	10	10	9	11
Average age (years)	18.5	18.8	18.6	18.2	18.6	19.3	19.2	19.5	19.3	19.1
Age range (years)	18–20	18–19	18–20	18–20	18–19	19–21	19–20	19–21	19–21	19–20
Freshman (%)	77	75	84	100	58	92	100	90	89	90
Female (%)	48	42	50	50	50	49	50	50	33	60
Male (%)	52	58	50	50	50	51	50	50	67	40
Race/ethnicity (%)										
Caucasian	59	58	30	75	67	69	80	80	33	72
Asian	22	25	30	8	17	15	10	20	33	0
Latino/Other	19	17	40	17	16	16	10	0	34	28
Degree programme (%)										
Liberal arts	17	20	10	0	40	23	20	20	10	45
Science/Engineering	82	80	90	100	60	71	80	80	80	55
Other	1	0	0	0	0	6	0	0	10	0

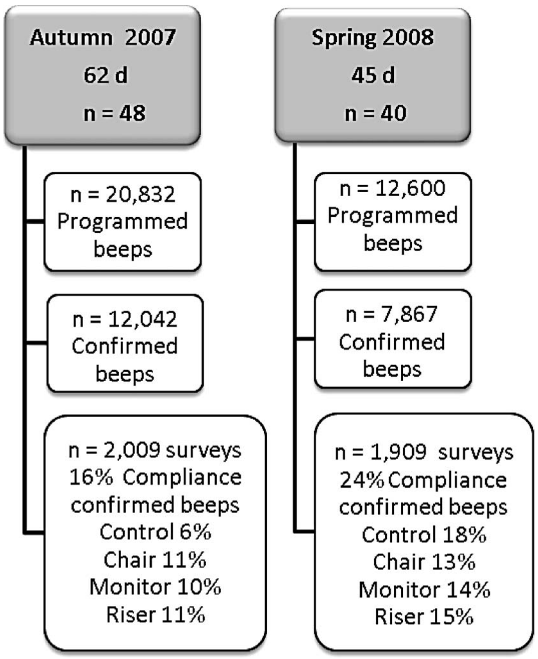

Figure 1. E-diary using personal digital assistant, participants' response to survey beeps.

(62 d × seven surveys/d); spring ranged from 4 to164 (mean = 48) out of a potential maximum of 315 (45 d × seven surveys/d). The number of surveys completed per day per participant ranged from zero to five for both studies. The overall number of autumn PDA person days per participant ranged from 1 to 47 d (mean = 21) out of a maximum of 62 d and for spring the number of person days ranged from 3–42 d (mean = 20) out of a maximum of 45 d. The number of surveys completed each week dropped off for both autumn and spring after week 4, from 15% to 3% by the last week of the study.

The PDAs were set to randomly 'beep' every 3.0–3.5 h for a total of seven beeps per day. For autumn, the PDA's 'beeps' were responded to most frequently at 17.00 hours, 21.00 hours, 22.00 hours, midnight and 01.00 hours. These responses accounted for 33% of all questionnaires completed for autumn. For spring, the 'beeps' were responded to most frequently at 17.00 hours and from 20.00 hours to 23.00 hours, these responses accounted for 56% of all questionnaires completed by spring. For both studies, 21.00 hours was the most frequent time of response; 7% for autumn and 16% for spring (Figure 2).

3.4. *Prevalence of self-report notebook computer-related discomfort*

Table 4 describes the autumn and spring distribution of self-reported UE musculoskeletal discomfort from

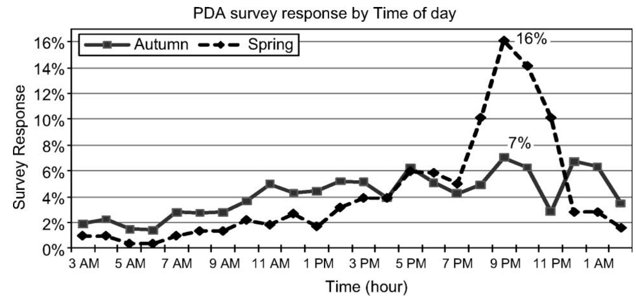

Figure 2. Participant's response to personal digital assistant (PDA) survey by time of day.

two sources: the Pre/Post Boston University Notebook Computing & Health Survey; the EMA PDA questionnaire.

3.5. *Boston University Notebook and Computer Health Pre/Post Survey*

Altogether, 53% of the students in autumn reported ever experiencing UE discomfort with notebook computing at baseline (start of the study) as compared with 58% post survey and 50% reported experiencing UE discomfort in the 2 weeks prior to completing the survey at baseline as compared with 40% post survey (Table 4). This compares with the spring findings, which reported 59% of participants ever experiencing UE discomfort at baseline and 55% post survey and 44% reporting experiencing UE discomfort in the 2 weeks prior to completing the survey at baseline vs. 25% post survey.

The chair group in the autumn study reported the largest decrease in UE discomfort from pre- to post-survey of 58% to 8%. The monitor and control groups both reported a decrease in UE discomfort from pre- to post-survey. The monitor group decreased from 75% to 66% and the control group decreased from 33% to 25%. The riser group reported an increase in discomfort to 58% from a pre-survey level of 33%.

The chair and riser groups in the spring study reported the largest decrease in UE discomfort from pre- to post-survey. The chair group decreased from 40% to 10% and the riser group decreased from 70% to 18%. The monitor group reported an increase in discomfort from 22% to 43% and the control group reported pre-survey discomfort of 40% and 38% for post-survey (Figure 3).

3.6. *PDA Questionnaire data: discomfort measured repeatedly over time*

The data were collapsed across the timeline of the intervention and repeated measure one-way ANOVA,

Table 4. Distribution of self-reported upper extremity (UE) discomfort: ever, past 2 weeks and current.

Autumn (n = 48)	Overall	Control	Chair	Monitor	Riser
UE discomfort with notebook computing	% (n = 48)	% (n = 12)	% (n = 12)	% (n = 12)	% (n = 12)
BU Computer & Health Survey: Discomfort measured at 1 point in time					
Ever: Pre-survey (Baseline: start of the study)	53	42	67	36	67
Ever: Post-survey	58	50	50	75	58
2 weeks: Pre-survey (Baseline: start of the study)	50	33	58	75	33
2 weeks: Post-survey	40	25	8	67	58
PDA Survey: Discomfort measured repeatedly over time					
Current: estimate slope (linear regression model 1 per participant)					
Decreased over time (adjusted for usage) [$\beta < 0$]	16	33	8	8	16
Increased over time (adjusted for usage) [$\beta > 0$]	6	0	8	8	8
No change over time (adjusted for usage) [$\beta = 0$]	78	67	84	84	76
Spring (n = 40)					
UE discomfort with notebook computing	% (n = 40)	% (n = 10)	% (n = 10)	% (n = 9)	% (n = 11)
BU Computer & Health Survey: Discomfort measured at 1 point in time					
Ever*: Pre-survey (Baseline: start of the study)	59	40	70	56	70
Ever*: Post-survey	55	75	30	43	73
2 weeks: Pre-survey (Baseline: start of the study)	44	40	40	22	70
2 weeks: Post-survey	25	38	10	43	18
PDA Survey: Discomfort measured repeatedly over time					
Current: estimate slope (linear regression model 1 per participant)					
Decreased over time (adjusted for usage) [$\beta < 0$]	15	30	0	11	18
Increased over time (adjusted for usage) [$\beta > 0$]	12	20	10	11	9
No change over time (adjusted for usage) [$\beta = 0$]	72	50	90	78	73

BU = Boston University; PDA = personal digital assistant.

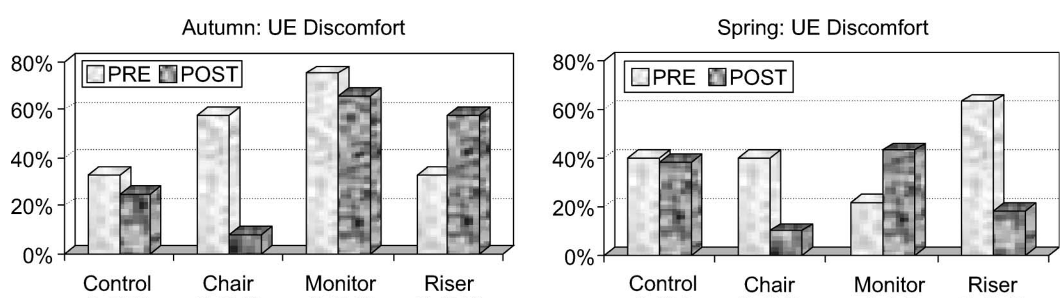

Figure 3. Upper extremity (UE) discomfort*: pre/post survey by group. *Pre/post survey question: 'In the past 2 weeks, have you experienced pain, discomfort, numbness, tingling or other pain/discomfort in your hands, wrists, arms, shoulders or neck when you use a notebook computer?'. N = number of subjects who completed pre-post survey.

Scheffe's method, was conducted to compare the three groups (chair, riser and monitor) with the control group on mean differences in UE discomfort by body region for the autumn and spring terms. The level for significance was set at $p \leq 0.05$ and findings for less discomfort by body part (Table 5) were significant for the ergonomic chair and notebook riser in the autumn term. The monitor was significant for increased

Table 5. Group comparisons ($p \leq 0.05$) ANOVA/Scheffe

Autumn: Differences in discomfort ANOVA ($p < 0.05$)	Accessory vs. Control group*		
Body region*	Riser	Chair	Monitor
Fingers	↓	↓	
Hands		↓	
Wrists		↓	
Forearms	↓	↓	
Elbows			
Upper arms			
Shoulders	↓	↓	
Neck		↓	
Lower back		↓	
Upper back			↑

↓Less discomfort than control group; ↑more discomfort than control group.
*19 questions from PDA Survey: discomfort using Likert score 1–5; 2 fingers, 2 hands, 4 wrist, 2 forearm, elbow, upper arm, shoulder, 1 neck, lower back, upper back.

discomfort in the upper back region. There was no significant difference in mean discomfort by accessory when compared with the control group for the spring term. The reduction in discomfort (Table 5) for the chair group in PDA mean values (one-way ANOVA test) is interesting because it is similar to the chair group pre/post-survey's findings (Table 4) and most likely benefited from the computer accessory.

To remedy these findings, which did not include the component of change-over time, the PDA discomfort data were further analysed over time using a linear regression model and adjusted for hours of daily notebook computer usage (Table 4). Individual regression models were conducted for each subject with current representing the direction of the subject's slope ($p < 0.10$). Longitudinally, over the duration of the study in the autumn, 16% of subjects experienced a decrease in discomfort over time, with similar findings of 15% for the spring. An increase in discomfort was experienced by 6% of the participants in the autumn and 12% of the participants in the spring. No change in discomfort level was experienced by 78% of the participants in the autumn and 72% in the spring. In both terms, the control group had the most participants with a decrease in discomfort over time. Paradoxically, the chair and monitor groups had the most participants where discomfort increased over time. The increases and decreases in discomfort, which emerged over time, as measured by the UE Index, show discomfort peaked in week five for the control and monitor groups, week six for the riser group and week seven for the chair group in the autumn term. The riser and control groups both had a decline in discomfort in weeks seven to nine. At the same time, participation declined to $\leq 50\%$ of students in the seventh week of the autumn term.

3.7. *Self-report notebook computer usage duration and rest breaks characteristics*

The pre-/post-survey's mean computer notebook usage for both groups was in the 4–6 h/d usage range, with the heavier use falling in the 6 + h/d. Post- vs. pre-survey reflects a decrease in notebook computer usage from the 6 + h/d category to an increase in the 4–6 h/d category for both autumn and spring groups. Overall, the spring participants' notebook computer usage in the 6 + h/d category was more than twice that of the autumn participants.

For autumn, both the monitor and riser groups reported a decrease from pre- to post-survey in usage from 8% to no usage in the 6 + h/d category, the control group reported 25% usage for both pre and post and the chair group reported a decrease from 33% to 16%. Overall, the chair and control groups reported the highest usage in the 6 + h/d category for autumn. The chair and riser groups reported the highest usage in the 6 + h/d category for spring.

Data regarding daily usage were obtained from two of the PDA survey questions: 'For how many hours have you been using your computer today?' and 'For how many hours have you been using another computer today?'. Possible responses to both of these questions ranged from 0, 1–2, > 2–4, > 4–6, > 6–8, > 8–10, > 10 h. Responses to both questions were combined to get one value of total daily computer use in hours for each survey response (Menéndez *et al.* 2008). PDA reported usage for 6 + h/d was < 10% for all groups in both autumn and spring. The daily average hours per day of computing were 4.1 for the autumn and 4.3 for the spring group and students reported using other computers for 33% of the time. On the last response of each day, 91% of the participants responded that they had not finished their computer use for the day. Thus, this daily usage was probably higher than indicated by this variable. About one-third of the participants reported taking a rest break at least once per hour. In the pre-survey, 58% of autumn participants reported working 4 + h without a break one or more times per week as compared with 31% of spring participants (Table 6).

3.8. *Knowledge of ergonomics*

Groups in both studies were homogeneous on their ergonomic knowledge 10-question quiz scores at pre-study, scoring an average of 70% correct, and post-study of 74%, with the same three questions having the highest frequency of error.

Table 6. Distribution of notebook computer use at baseline: pre survey.

Characteristics: Source pre-survey (baseline) %	Autumn	Spring
	n = 48	n = 40
Use notebook computer for ≥ 90% computing vs. desktop	89	87
Primary location of notebook computing: dorm room	81	87
Location of most of notebook computing in dorm room: desk	80	87
Use an external device with notebook computer: none	32	56
Use an external mouse	44	41
Use an external monitor	6	5
Use an external keyboard	6	5
Daily computer use 2–4 h	*36*	*18*
Daily computer use 4–6 h	38	36
Daily computer use 6 + h	19	42
Take breaks at least once per hour	33	31
Take breaks specifically to rest or stretch once every 1–2 h	27	36
Never takes computer breaks or only after ≥ 2 h computing	15	23
Work 4 + h without a break ≥ 1 times/week	58	31

4. Discussion

This study examined the effects of an intervention consisting of participatory ergonomics training combined with one of three notebook computer accessories, an adjustable computer chair, notebook riser and a desktop monitor on musculoskeletal discomfort, using two different self-report methods to assess the computer accessories. The pre-intervention survey found that students reported discomfort related to computer use. Altogether, 50% of the autumn group and 44% of the spring group reported experiencing discomfort in the preceding 2 weeks from baseline. This is consistent with prior research reporting prevalences in the range from 41% to 54% (Katz *et al*. 2000, Hupert *et al*. 2004, Jenkins *et al*. 2007, Menéndez *et al*. 2007).

The two week pre-post intervention survey (Figure 3) indicated a decrease in discomfort for the chair groups in both the autumn (decreased from 58% to 8%) and spring (40–10%) terms and the riser group spring (70–18%). While it is plausible that the chair and notebook riser contributed to the student's decrease in discomfort, the PDA records showed consistently lower daily notebook computer use in these two groups in the autumn term (Figure 4). Thus, the difference in symptoms could be the result of confounding by hours of usage per day. The regression models illustrate that, after adjusting for daily notebook use, the chair and riser groups no longer had the greatest decreases in discomfort. Therefore, it is unlikely that the change in outcome can be attributed entirely to the chair/riser and ergonomic training. Findings for the change in discomfort over time, based on the regression analysis from the PDA data, were both surprising and unexpected for the control and chair groups based on the findings of the pre-post intervention survey. Using the UE Index as the dependent variable and survey date (elapsed time from beginning of the intervention) as the independent variable, the control groups in both terms had a large proportion of students with decreased discomfort over time (adjusted for daily computer usage), whereas few students in the chair groups had decreased symptoms over time. These findings seem counter intuitive to those found based on the Pre/Post Computing and Health surveys and may perhaps be attributed to the less than 25% compliance rate for the PDA questionnaire.

While electronic diaries are increasingly used to assess daily pain in many different forms and populations (Morren *et al*. 2009), the use of EMA to obtain repeated real-time assessments of university students' discomfort remains novel. The literature on the use of PDAs for EMA led to the expectation of a decline in compliance over time. The degree of non-compliance that was observed was surprising. Prior studies reported compliance rates for e-diaries of 50–91% (Aaron et al. 2004, Shiffman et al. 2008, Morren et al. 2009), in contrast to paper diary compliance, ranging from 11% to 39% (Stone *et al*. 2003a, Broderick 2008). A systematic review of EMA with electronic diaries (Morren et al. 2009) found a mean compliance rate of 83% across studies. Those with higher compliance contained surveys of less than 20 questions, no more than six prompts per day, for 1 month at most, and financial compensation to participants. Only one study was found, which used EMA by means of PDAs to measure discomfort in a university population (Menéndez et al. 2007). This investigation measured students' UE MSD symptoms for three separate 1-week periods with five prompts per day. There were no drop-outs, but the response rate for the PDA questionnaires varied from 37 to 135 per day per person, the mean completed per week was 24 and the overall compliance rate was greater than 50%.

Thus, it was surprising that, in the present study, only 16–24% of the PDA surveys were completed in compliance with the protocol, even fairly early in the study. It is believed that the higher rate of response for the spring term could be attributed to the additional incentive to win an IPod at the end of the study.

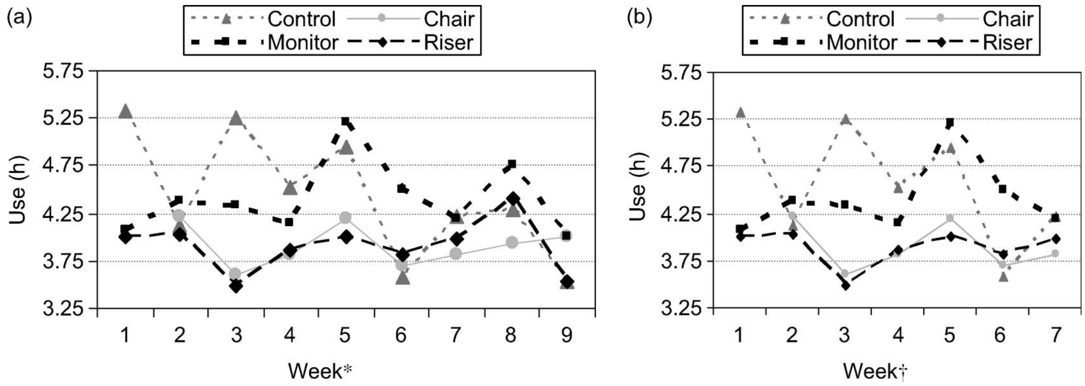

Figure 4. Personal digital assistant (PDA) usage – hours per day of computing by week by group: (a) autumn. *Week based on 5 d of classes, week 1 began 4 weeks into the autumn semester. Holidays shortened weeks 6 and 8 by 1 d, week 7 by 2 d. Autumn semester began 4 September 2007, ended 12 December 2007; (b) spring. †Week based on 5 d of classes, week 1 began after spring break, 9 weeks into the spring semester. Holidays shortened week 6 by 1 d. Spring semester began 16 January 2008, ended 1 May 2008.

Tickets for the drawing were awarded based on the number of surveys completed each week.

The number of questionnaires collected per participant ranged from one to 164 with a mean = 5 per week, resulting in large chunks of missing data both within-subject and between groups. These low compliance rates were highly discouraging and have important implications for the validity of the PDA data by introducing potential systematic bias due to the self-selection of completion times (Stone *et al.* 2003b). Missing data may bias study results and interpretations (Aaron *et al.* 2004). Piasecki *et al.* (2007) noted that the validity of the data may be severely threatened if participants cannot shoulder the repeated measures burden and deviate from the electronic diary protocol. In the current study, it is believed that it may have had a large effect on the prevalence results obtained from the repeated measures data. In particular, the non-compliance may have had a differential impact on symptom reporting, in that those without discomfort at a given moment may have been less likely to reply to a PDA prompt. After a few days, the participants would have learned the content of the survey as well as the time required to answer it. This potential selection bias could have obscured any true downward trends in symptom occurrence over time.

With seven prompts per day for 7–9 weeks, to complete a 45-question survey, it was anticipated that the EMA would place a burden on the students as they went about their daily activities and it was expected that the weekly incentives would encourage compliance. Another concern was that the students would rush through the 45-question survey, which might negatively affect the data quality. Reasons for non-compliance included both technical issues, such as battery problems, loss of PDA data due to power failures or other technical difficulties and PDA malfunction, and logistical issues, such as the lack of a vibration mode convenience feature for suspending the 'beeping' during sleep or classes (which led some to store the PDA in their sock drawer to dampen the 'beep' sound), lapses of motivation, being too busy and beeping at inconvenient times. Some of these same reasons for non-compliance were noted by Dale and Hagen (2007).

Similar computing patterns were found between the autumn and spring terms. Of those who responded to the PDA prompts, 39–42% were using their notebook computer at the time of the survey, 80–86% were computing at their desk. The greatest number of survey responses took place at 21.00 hours, with the highest response occurring between 21.00 hours and midnight. This information may be useful in designing a future study where repeated measure surveys are used.

Another possible source of differences between the outcome measures of the autumn and spring terms may be due to a difference in timing/academic workload and duration of the intervention. The autumn intervention began 5 weeks after the start of the semester and lasted 62 d and the spring intervention began 8 weeks after the start of the semester, commencing upon return from spring break and lasting 45 d. The academic workloads may have been different in addition to the day-to-day variation related to the function of change in the hours per day of notebook computer usage. It is quite plausible that there might also have been a cumulative usage effect for the spring term as compared with the autumn.

These data suggest that both hours of notebook computing per day and UE discomfort changed over time, and often in a non-linear fashion. Few studies have examined this relationship over time. A future longitudinal study might look to explore the rate of change in discomfort as a function of notebook computer usage using a larger sample size and a less burdensome and resource-intensive EMA protocol.

Students reported during their weekly visits with the researchers that the ergonomics training was beneficial. For example, they described being more proactive in making adjustments to their posture when computing and having developed a greater awareness as to what constitutes healthy computing. This awareness may have contributed to the shift in daily usage by the end of the study, with a post-survey 10% decrease in notebook computing 6 + h/d and a corresponding increase in those computing 4–6 h/d. Students' improvements in ergonomics quiz scores were comparable between the autumn and spring groups (75%) and most scored the same three questions incorrectly. Those in the chair group found the adjustable chair to be very comfortable and many wanted to purchase one for their own use. Given that the desks and chairs in most dorm rooms are non-adjustable, and that 78–82% of the students reported that they do most of their computing at their desks, it is likely that awkward postures may contribute to discomfort. However, it is not possible to conclude from the results that the computer accessory was entirely responsible for the decrease in discomfort, due to probable confounding by group by hours per day of notebook computer usage. Students found the adjustable chair to be the most convenient accessory to use and it was their first choice of accessories if they had to choose one.

Mean hours per day of computer use was 4.1–4.3, similar findings of 4.1 h for undergraduate students weekday computing was found by Noack-Cooper *et al.* (2009). Asundi *et al.* (2010) found wrist, neck and head postures were relatively poor in all the portable configurations tested. Therefore, it is recommended that users limit the use of notebook computers in the portable environment, change posture frequently to reduce the risk of injury and/or take frequent breaks. Based on these findings, many students are at risk for developing MSDs or becoming symptomatic prior to entering the workforce. This is especially true because ergonomic friendly workstation set-up and healthy computing educational awareness programmes are typically not part of the health services that universities offer to their students. This low level of awareness could be heightened at minimal costs to universities by updating computer laboratories to include accessories for students to try out and allocating room for a demonstration of an ergonomic set-up of a typical dorm room workstation. Straker *et al.* (2010) reviewed the evidence regarding the physical aspects of child–computer interaction and provided recommendations for the wise use of desktop/notebook computers, many of which could be applied to university students' use of notebook computers.

Many universities establish a student discount programme for purchasing notebooks and PCs from a select group of manufactures. They could expand upon this and offer discounted ergonomic chairs and ergonomic notebook computer accessories.

The availability of adjustable furniture in dorm-rooms, computer laboratories, libraries and student centres may be non-existent due to lack of funding. Raising the administration's awareness of the risk factors that university students face may support a policy of allocating funding for adjustable furniture at the time when new dorms are being built and furnished, in addition to upgrading furnishings when existing dorm rooms are being refurbished. It may also support the need for implementing an ergonomics training programme for all incoming freshman, perhaps at freshman orientation, which informs students about MSDs and the relationship to poor computing habits. Ergonomics can provide and promote guidelines for wise use of computers and, by doing so, promote the positive effects and reduce the negative effects of computer interaction (Straker *et al.* 2009b).

At this time, information could also be provided about sources of computer accessories offered at a student discount.

A limitation of this study was the possible selection bias attributed to the low compliance and attrition. Future studies should identify methods to increase compliance, such as an online survey scheduled for 21.00 hours and each half hour thereafter until 12 midnight, fewer questions, reduced daily frequency and duration and the use of smart phones in lieu of PDAs. Another limitation included time constraints and lack of engagement over time. Students reported using other computers for 33% of the time; this may have diluted the intervention's effectiveness. A possible explanation for this 33% may be computing in the library. Students commented that their rooms in the freshman dorm (built in 1965) are small, cramped and kind of like a prison cell. The library offered a more desirable study environment.

To increase compliance of responding to daily or weekly surveys (Figure 1), future research might look at incorporating more innovative strategies, such as 3-D game technology, to increase student's engagement, interest and skills throughout the intervention and the use of online surveys by means of smart phones instead of PDAs. A short online survey with less than 10 questions would take less time and allow for real-time access by the researchers. The surveys could be limited to two per day to minimise the burden on the participants. Other ideas include the establishment of a Facebook group for the purpose of communication, personal coaching and feedback with participants and incentives tied to participation or goals.

5. Conclusions

Findings showed mixed evidence in answer to: 'Do computer accessories, combined with training, reduce use-related discomfort?'. Evidence was found of a positive effect of an adjustable chair or riser when combined with training on reducing discomfort based on the pre-post survey data and the e-diary/PDA ANOVA analysis. The UE Index from the PDA data, adjusted for the effect of use, showed no benefit of the chair and limited benefit from the riser. A method using e-diaries/PDAs was added to get greater precision of self-reported change in discomfort over time but it was found to be ineffective due to low compliance. It was found that daily hours of notebook computer use of 4.1 and 4.3 h was confirmed as a risk factor.

It is the combination of ergonomic training and workstation adjustments incorporating computer accessories that will most likely generate the greatest success in preventing or reducing MSDs as a result of using notebook computers (Amick *et al.* 2008, van Eerd *et al.* 2010). Without some form of intervention, university students are likely to enter the workforce with poor computing habits and this may place them on a road to increasing risk of MSDs as computer technology continues to play a dominant role in their lives.

Acknowledgements

Research support for these studies was provided by pilot project grants awarded by the Office of Ergonomics Research Committee (OERC), Boston University Grants for Undergraduate Teaching and Scholarship (GUTS), Boston University: University of Health and Rehabilitation Sciences: Sargent University (matching funds), Harvard-NIOSH Education and Research Center under Grant No. 2 T42 OH008416–05. Special thanks to the OERC, in particular, Michael Bartha and Dan O'Dell, Hewlett Packard, All Steel, Logitech, Wellnomics, Peter Johnson, PhD, University of Washington, and Jack Dennerlein, PhD, Harvard University.

References

Aaron, L.A., *et al.*, 2004. Reasons for missing interviews in the daily electronic assessment of pain, mood, and stress. *Pain*, 109 (3), 389–398.

Amick, B.C., *et al.*, 2008. *Systematic review of the role of occupational health and safety interventions in the prevention of upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time*. Toronto: Institute for Work & Health.

Amick, 3rd, B.C., *et al.*, 2003. Effect of office ergonomics intervention on reducing musculoskeletal symptoms. *Spine*, 28 (24), 2706–2711.

Asundi, K., *et al.*, 2010. Notebook computer use on a desk, lap and lap support: effects on posture, performance and comfort. *Ergonomics*, 53 (1), 74–82.

Baker, N.A., Jacobs, K., and Carifio, J., 1999. The ability of background factors, work practices, and psychosocial variables to predict the severity of musculoskeletal discomfort. *Occupational Ergonomics*, 2 (1), 27–41.

Bernard, B.P., *et al.*, 1997. *Musculoskeletal disorders and workplace factors* [online]. DHHS (NIOSH) Publication No. 97–141. Washington, DC: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Available from: http://www.cdc.gov/niosh/docs/97-141/97-141pd.html [Accessed 9 October 2010].

Broderick, J.E., 2008. Electronic diaries: appraisal and current status. *Pharmaceutical Medicine*, 22 (2), 69–74.

Bureau of Labor Statistics (BLS), 2009. 2008 nonfatal occupational injuries and illnesses, private industry. Available from: http://www.bls.gov/iif/osh/case/osch0040.pdf. [Accessed May 2010].

Chang, C.H., *et al.*, 2007. Daily computer usage correlated with undergraduate students' musculoskeletal symptoms. *American Journal of Industrial Medicine*, 50 (6), 481–488.

Dale, O. and Hagen, K.B., 2007. Despite technical problems personal digital assistants outperform pen and paper when collecting patient diary data. *Journal of Clinical Epidemiology*, 60 (1), 8–17.

Gold, J.E., Punnett, L., and Katz, J.N., 2006. Pressure pain thresholds and musculoskeletal morbidity in automobile manufacturing workers. *International Archives of Occupational and Environmental Health*, 79 (2), 128–134.

Hupert, N., *et al.*, 2004. Upper extremity musculoskeletal symptoms and functional impairment associated with computer use among college students. *Work*, 23 (2), 85–93.

Jacobs, K., *et al.*, 2009. University students' notebook computer use. *Applied Ergonomics*, 40 (3), 404–409.

Jenkins, M., *et al.*, 2007. Undergraduate college students' upper extremity symptoms and functional limitations related to computer use: a replication study. *Work*, 28 (3), 231–238.

Katz, J.N., *et al.*, 1994. Responsiveness of self-reported and objective measures of disease severity in carpal tunnel syndrome. *Medical Care*, 32 (11), 1127–1133.

Katz, J.N., *et al.*, 2000. Prevalence of upper extremity musculoskeletal disorders in college students. *American Journal of Medicine*, 109 (7), 586–588.

Koop, A. and Mösges, R., 2002. The use of handheld computers in clinical trials. *Controlled Clinical Trials*, 23 (5), 469–480.

Lancaster, L.C. and Stillman, D., 2010. *The M-factor: How the Millennial generation is rocking the workplace*. London: Harper Business.

Menéndez, C.C., *et al.*, 2007. A multi-method study evaluating computing-related risk factors among college students. *Work*, 28 (4), 287–297.

Menéndez, C.C., *et al.*, 2008. Computer use patterns associated with upper extremity musculoskeletal symptoms. *Journal of Occupational Rehabilitation*, 18 (2), 166–174.

Morren, M., *et al.*, 2009. Compliance with momentary pain measurement using electronic diaries: a systematic review. *European Journal of Pain*, 13 (4), 354–365.

Noack-Cooper, K.L., Sommerich, C.M., and Mirka, G.A., 2009. College students and computers: assessment of usage patterns and musculoskeletal discomfort. *Work*, 32 (3), 285–298.

Piasecki, T.M., *et al*., 2007. Assessing clients in their natural environments with electronic diaries: rationale, benefits, limitations, and barriers. *Psychological Assessment*, 19 (1), 25–43.

Punnett, L. and Bergqvist, U., 1997. *Visual display unit work and upper extremity musculoskeletal disorders*. Ergonomic Expert Committee Doc No. 1. 1997:16. National Institute for Working Life. Available from: http://gupea.ub.gu.se/bitstream/2077/4159/1/ah1997_16.pdf. [Accessed October 2009].

Robertson, M.M., *et al*., 2002. Effects of a participatory ergonomics intervention computer workshop for university students: a pilot intervention to prevent disability in tomorrow's workers. *Work*, 18 (3), 305–314.

Samuelson, R., 2010. The real generation gap young adults are getting slammed. Newsweek, 3 May, 2010. Available from: http://www.newsweek.com/2010/03/04/the-real-generation-gap.html [Accessed May 2010].

Sauter, S.L., Schleiffer, L.M., and Knutson, S.J., 1991. Work posture, workstation design, and musculoskeletal discomfort in a, VDT data entry task. *Human Factors*, 33 (2), 151–167.

Shiffman, S., Stone, A.A., and Hufford, M.R., 2008. Ecological momentary assessment. *Annual Review of Clinical Psychology*, 4, 1–32.

Smith, S., Salaway, G., and Borreson Caruso, J., 2009. *The ECAR study of undergraduate students and information technology, 2009* [online]. Research Study, Vol. 6. Boulder, CO: EDUCAUSE Center for Applied Research. Available from: http://www.educause.edu/ecar [Accessed 15 May 2010].

Sommerich, C.M., *et al*., 2002. Effects of notebook computer configuration and task on user biomechanics, productivity and comfort. *International Journal of Industrial Ergonomics*, 30, 7–31.

Stone, A.A., *et al*., 2003a. Patient compliance with paper and electronic diaries. *Controlled Clinical Trials*, 24 (2), 182–199.

Stone, A.A., *et al*., 2003b. Intensive momentary reporting of pain with an electronic diary: reactivity, compliance, and patient satisfaction. *Pain*, 104 (1–2), 343–351.

Straker, L., Jones, K.J., and Miller, J., 1997. A comparison of the postures assumed when using laptop computers and desktop computers. *Applied Ergonomics*, 28 (4), 263–268.

Straker, L., Pollock, C., and Maslen, B., 2009a. Principles for the wise use of computers by children. *Ergonomics*, 52 (11), 1386–1401.

Straker, L., *et al*., 2009b. The influence of desk and display design on posture and muscle activity variability whilst performing information technology tasks. *Applied Ergonomics*, 40 (5), 852–859.

Straker, L., *et al*., 2010. Evidence-based guidelines for the wise use of computers by children: physical development guidelines. *Ergonomics*, 53 (4), 458–477.

Strazdins, L. and Bammer, G., 2004. Women, work and musculoskeletal health. *Social Science and Medicine*, 58 (6), 997–1005.

van Eerd, D., *et al*., 2010. Process and implementation of participatory ergonomic interventions: a systematic review. *Ergonomics*, 53 (10), 1153–1166.

Villanueva, M.B., Jonai, H., and Saito, S., 1998. Ergonomic aspects of portable personal computers with flat panel displays (PC-FPDs): evaluation of posture, muscle activities, discomfort and performance. *Industrial Health*, 36 (3), 282–299.